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Design and On-Orbit Performance of the Attitude Determination and Passive Control System for the Quetzal-1 CubeSat

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Abstract

Quetzal-1, a 1U CubeSat developed by Universidad del Valle de Guatemala, operated on orbit from April to November of 2020. It included an in-house developed passive attitude determination and control system (ADCS) based on a previous mission from a different team, the Colorado Student Space Weather Experiment (CSSWE). Quetzal-1's ADCS used a $0.74 \text{ A}\cdot\text{m}^2$ magnet to align the satellite to Earth's magnetic field. Due to volumetric constraints, Quetzal-1 only incorporated two hysteresis rods in contrast to CSSWE, a 3U CubeSat that carried six of them. The rods were located on mutually orthogonal axes to stabilize its rotation. Earth's magnetic field inclination over Guatemala, the mission's geographical zone of interest, informed the location of the ADCS components and the camera with respect to the satellite's structure to maximize the probability of target image acquisition. A Singular Value Decomposition (SVD) method was implemented for attitude determination together with a three-axis magnetometer and two photodiodes on each of the satellite's six sides. Within a week of deployment from the International Space Station (ISS), Quetzal-1's ADCS was capable of stabilizing rotational rates from $\pm 25 \text{ }^\circ/\text{s}$ to $\pm 3.5 \text{ }^\circ/\text{s}$ per axis. Additionally, it correctly aligned the satellite to the magnetic field vector to within 14.28° . The ADCS' gyroscope operated nominally, while the magnetometer occasionally transmitted all-zero data at temperatures below 10°C . Most importantly, the ADCS enabled the payload to acquire images. The results and performance of Quetzal-1's ADCS, from per-component and systemic perspectives, are described in this manuscript, including the impact of flights over the South Atlantic Anomaly (SAA) on the magnet's torque and oscillation amplitudes. Detailed description of the design approach, component selection criteria, results, and recommendations based on lessons learned may be valuable to other teams developing their own CubeSat passive ADCS.

1. Introduction

Quetzal-1 (ket-sahl-oo-noh) was a 1U CubeSat developed by Universidad del Valle de Guatemala

(UVG) and supported, in terms of its launch to and deployment from the International Space Station (ISS), by the United Nations Office for Outer Space Affairs (UNOOSA) and the Japan Aerospace Exploration

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